

**DISTRIBUTION AND ABUNDANCE OF MANGROVE VEGETATION IN
THE DISTURBED ECOSYSTEM OF SEGARA ANAKAN, CENTRAL JAVA**
(*Distribusi dan Kemelimpahan Vegetasi Bakau di Ekosistem Hutan Rusak
Segara Anakan Jawa Tengah*)

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Abstract

The Segara Anakan mangrove from 1980 up to the present has experienced heavy siltations and mangrove-tree cutting. The siltation of 4.5 million tons per year from the watershed of Citanduy River create a lot of newly formed land and shoals, which disturbed the pattern of tidal flow and tide periods. In 1997 large areas of mangroves were converted to shrimp ponds which failed and were abandon. The purpose of this research was to study the response of mangrove vegetation to the changing of the Segara Anakan ecosystem. This study compared the area which experienced only heavy siltation and tree cutting with the area experienced only tree cutting. The transect methods with quadrat plots were used in collecting data. The results showed that there were 16 species of mangrove and one aquatic macrophyte. Almost all of the areas were colonized by the shrub, *Acanthus ilicifolius*, and liana-shrub, *Derris heterophylla*. Both of these species had r and k strategies, which had coverage almost 100%, and had consecutive 83583 and 23938 densities shrubs per ha. The dominant tree species were *Sonneratia alba* with 485 trees per hectare and *Avicennia alba* with 203 trees per hectare. However, the distribution and abundance of mangrove trees were determined by the tree cutting activities, and they were not determined by the high siltation rate and salinity. The combination between heavy siltation, mangrove tree cutting, land clearing and the climate change worsen the Segara Anakan mangrove ecosystem. Therefore, the mangrove of Segara Anakan was a critically endangered ecosystem.

Keywords: changing mangrove ecosystem, *Acanthus ilicifolius*, *Derris heterophylla*, mangrove trees, siltation

Abstrak

Hutan bakau Segara Anakan sejak tahun 1980 sampai sekarang mengalami siltasi yang sangat tinggi dan penebangan pohon bakau. Setiap tahunnya menerima 4,5 juta ton sedimen dari daerah tangkapan air Citanduy, dan mengakibatkan terbentuknya pulau-pulau baru dan dangkalan di lagunanya. Keadaan ini telah mengganggu pola arus dan pasang surut. Pada tahun 1997, hutan bakau tersebut dalam skala luas telah diubah jadi tambak udang, akan tetapi tidak berhasil dan ditinggalkan sebagai tambak rusak. Tujuan penelitian ini mempelajari respon vegetasi hutan bakau terhadap perubahan ekosistem Segara Anakan, dengan membandingkan lokasi hutan bakau yang mengalami siltasi berat dan penebangan pohon bakau dengan lokasi yang hanya ditebang pohon bakaunya saja. Metode yang digunakan adalah kuadrat plot dengan bantuan garis transek. Hasil menunjukkan bahwa ada 16 jenis mangrove dan satu akuatik makrophyta. Hampir seluruh hutan bakau dikoloni oleh semak dan liana bakau, *Acanthus ilicifolius*, dan *Derris heterophylla* dengan penutup hampir 100%. Densitasnya berurutan adalah 83583 and 23938 per ha. Ke dua spesies tersebut bersifat r dan K strategi. Pohon dominan *Sonneratia alba* adalah 485 per ha, dan *Avicennia alba* with 203. Distribusi spesies pohon bakau ditentukan oleh aktivitas penebangan pohon, bukan oleh sedimentasi dan salinitas. Kombinasi antara siltasi yang tinggi, penebangan pohon bakau, dan perubahan iklim telah memperburuk kondisi hutan bakau, sehingga hutan bakau Segara Anakan dapat dikategorikan sebagai ekosistem terancam kritis.

Kata kunci: Perubahan ekosistem hutan bakau, Acanthus ilicifolius, Derris heterophylla, pohon bakau, siltasi.

INTRODUCTION

The Segara Anakan mangrove is in the process of changing to freshwater wetland due to heavy sedimentation, 4.5 million tons per year (Napitupulu and Ramu 1982; Djohan 2007). If the sedimentation rate was persistent, thus in 2010 the Segara Anakan estuary will be filled by the sediment and changed into a different ecosystem (Napitupulu and Ramu 1982). The siltations create a lot of newly-formed lands, shoals, and pro-grading lands. The shoals were detrimental to the mangrove ecosystem because they prevent the normal tidal frequency in the estuary (Hamidjoyo 1982; Hadisumarno et al. 1982). Suryowinoto (1982) reported that in 1980 there were 35 species of mangrove plants were found in this ecosystem. Certainly the newly-formed lands were colonized by the mangrove species (Djohan 2007).

In addition to the heavy siltation, this ecosystem also had stress from selective tree-species cutting (Sunaryo 1982; Djohan 2007). Moreover between 1996-1997, large areas of the mangrove vegetation were reclaimed to shrimp ponds, which were unsuccessful and abandoned. In the 2002, the change of this ecosystem was recognized, during the rainy season, the water salinity was 0 ‰, and during dry season was between 20-32 ‰ (Djohan 2002). Thus the communities of the Segara Anakan mangrove ecosystem will respond to this environmental change. There were many studies in the field of neo-tropical mangrove dynamics (Ball 1980, Sherman et al. 2000; Piou et al. 2006). However, there was not much information about the mangrove dynamics in the old- world tropical mangrove (Sukarjo 1999).

Piou et al. (2006) reported on forty-one years of the mangrove succession after the catastrophic hurricane category 5 on Belize offshore. They stated that the disturbance from that hurricane was as a potential factor

for the horizontal mangrove distribution. Ball (1980) reported the effect of salinity in relation to the succession pattern of Florida mangrove. This ecosystem at the beginning was influenced by riverine-freshwater. Ball studied the pure stands of *Rhizophora mangle* and the mixed stand between *Rhizophora* and *Laguncularia*, which were established in the saline areas of the intertidal zone. These stands were compared to the *Laguncularia* at the upper zone. The result showed that both *Rhizophora* and *Laguncularia* were sparse, thin, and short. This area was in the process of succession to *Rhizophora*, but the *Laguncularia* failed to compete, and only grew in the drier soil. Sherman et al. (2000) studied the dynamics of mangrove regeneration in an area which had experienced of the low-grade disturbance in Dominican Republic. They reported that the small disturbance maintained mangrove forest diversity. But the failure of peat-land created gaps which were inundated by water and it also increased the water level. As a result these canopy gaps were colonized by *R. mangle*.

In the Segara Anakan, the mangrove dynamics was due to the heavy siltation and the selective tree cutting of mangrove species such as *Bruguieras* spp, *Rhizophora* spp, and *Avicennia* spp. Djohan (2007) reported the colonization of mangrove-tree species was not as she predicted in the 1984. She had thought it would be dominated by *Avicennia alba* and *Rhizophora apiculata*, but it did not happen. The dominant tree species was *Sonneratia alba*, and the open areas were dominated by mangrove shrub, *Acanthus ilicifolius* and liana *Derris heterophylla*. She reported that based on the remnant of tree stumps, there was an indication that people cut selective tree species, as follows: first they cut *Bruguiera* and *Rhizophora*, then *Avicennia*. She also reported that the seedlings of *Sonneratia alba* colonized the newly-formed lands at the lower zones, then was followed by

propagules of *Avicennia alba*. However, when the sere matured, the dominant tree was *Avicennia*. In the gap canopy, *Rhizophora* trees were shifted to *Aegiceras corniculatum*, *Acanthus ilicifolius*, and *Derris heterophylla*. The successions of mangrove vegetation were not only forced by the heavy siltations, but also the availability of mangrove propagules, and seeds from the adjacent areas. In the Segara Anakan mangrove, there were no patterns of species zonation from the lower to upper zones.

The mangrove ecosystem has significant roles in food chains based on the detritus of mangrove-tree species. These detritus give the ecological services not only for the mangrove ecosystem itself, but also to the sea-scape. Their services are not only to the ecological species, but also to the economic species of coastal and open-sea fisheries. In addition, their ecological services also give protection from abrasion of the beach, and protect the settlements at the back-swamp from the tsunami. Moreover, this ecosystem functions as spawning and nursery grounds for not only ecologically valued species, but also for the species of shrimps and fish which have highly economic values (Odum 1971; Ronnback 1999; Mitch and Gosselink 2000). Indonesia is an archipelago country, thus a healthy mangrove ecosystems play an important role not only for the mangrove ecosystem itself, but also for the coastal and open-sea fisheries. However, the present conditions of these ecosystems, such as in the Segara Anakan, are threatened to the mangrove-tree cutting, the conversion to unsuccessfully shrimp ponds, and also the bad management of watershed areas which resulted in heavy siltation in the estuary (Djohan 2007).

The purpose of this research was to study the response of mangrove vegetation to the changing of Segara Anakan mangrove ecosystem. This study questioned: how was the shifted species composition of the mangrove vegetation?; what was the new dominant species emerged?; How were the qualities of soil nutrients of NO_3 , NH_4 , and PO_4 , C-organic, FeS_2 , the soil texture, and also the water salinity.

METHODS

This study was carried out in May 2007 in the Segara Anakan mangrove at three locations (Figure 1). Two locations was at Bondan-Wates and Monggor, which were in the Segara Anakan lagoon. One location was outside the lagoon at Kali Gatal along the Kembang Kuning River. The mangrove at Bondan-Wates and Monggor were influenced by the heavy siltation, and tree cutting Bondan-Wates was old-formed land, and Monggor was newly formed land. At Kali Gatal, the mangrove was only influenced by tree cutting. The soil qualities of NO_3 , NH_4 , PO_4 , C- organic and FeS_2 , texture, and water salinity were studied. The combinations of transects and quadrat plots were used in collecting data for mangrove plant species and also soil samples (English et al. 1994).

At each location, two transects were established crossed the study area at several zones. In each transect two quadrat plots were placed based on the dominant vegetation. At Bondan, the transect crossed at 5 zones, which were lower- upper (Z1); middle- middle (Z2); upper- upper (Z3); upper- middle (Z4); zone upper- lower (Z5). The transects at Monggor area crossed three zones, which were zone lower- upper (Z1); upper- upper (Z2); and zone lower- upper (Z1). At Kali Gatal, the transect crossed at 2 zones, which were middle- middle (Z1) and upper- upper (Z2). The sizes of quadrat plots were 20m x 20m for the tree species, 1m x 1m for the shrubs, and 0.5m x 0.5m for the aquatic macrophyte. At each zone, the quadrat plots had 2 replicates for the tree, 5 replicates for the shrub and liana species, and 10 replicates for the aquatic macrophyte. The data were collected during the low tide. The measured parameters were number of individual species of plant communities which included plant cover, density, and basal area.

The soil nutrients were measured using composite samples from quadrat plot of each zone of each location. The NO_3 was measured with Brucine method, NH_4 with Nessler method, PO_4 with Bry method, FeS_2 with Colorimetric, and C-organic with Wakley-Black with volume metric method.

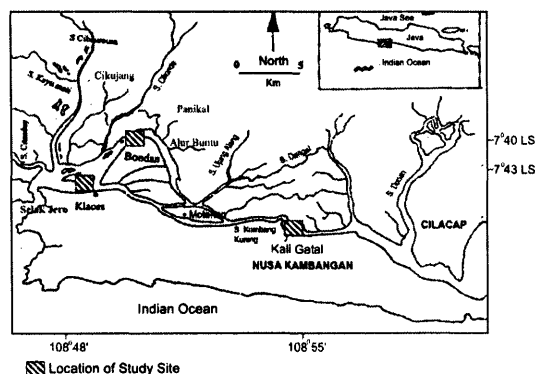


Figure 1. The locations of study area were at Bondan-Wates, Monggor, and Kali Gatal. The locations of Bondan-Wates and Monggor were inside the lagoon of Segara Anakan, and the Kali Gatal was out side the lagoon, which was at Kembang Kuning River.

Soil samples were collected during low tide using soil core from soil surface to 15 cm depth. The surface-water salinities were measured during high-tide from the adjacent water next to the study location. The soil textures were measured with pipette based on Stoke Law. The water salinity of each location was measured using hand refractometer with two replicates.

RESULTS AND DISCUSSIONS

Mangrove vegetation – There were 16 mangrove species, and one species of aquatic macrophyte (Fig. 2; Fig. 3). This vegetation were composed of 7 growth-forms of the mangrove tree, sapling, and seedling, shrub, liana-shrub, palm, and mangrove fern, and one species of macrophyte. These mangrove tree species were *Sonneratia alba*, *S. caseolaris*, *Avicennia alba*, *Rhizophora apiculata*, *R. mucronata*, *Brugueira gymnorhiza*, *B. parviflora*, *Aegiceras corniculatum*, *Xylocarpus molluccensis*, and *X. granatum*, *Heritiera litoralis*. The mangrove shrub species was *Acanthus ilicifolius*, and the woody liana species were *Derris heterophylla*, and *Finlaysonia obovata*. The mangrove palm species was *Nypa fruticans*, and *Acrostichum aureum*, and the aquatic macrophyte was *Cyperus mallaccensis* (Fig.2). The *C. mallaccensis* was found only at Monggor.

These tree species were distributed scarcely at all the study sites of Bondan, Monggor, and Kali Gatal. Bondan had only 4 species of trees, *S. alba* and *A. alba*, *A. corniculatum* and *Nypa fruticans*. which were very low in comparison to the Monggor tree-species, which were composed of 7 species of trees. Kali Gatal had 10 tree species, which was the highest number of tree species in all studied area. The present of tree species was disturbed due to the intensive of *Sonneratia alba* tree-cutting in the mangrove forest both at the old-formed land and the newly- formed land of Bondan-Wates and Monggor. It seems at Monggor, these trees had small diameter and were not cut yet, but very soon these tree species also will be cut down.

The loss of tree species caused the mangrove zones were not performed. As a result the mangrove succession was still dictated by the availability of the tree-propagules from the neighboring forest. The *Sonneratia* tree cutting created large forest gaps which were directly colonized by the mangrove shrub and liana, *Acanthus ilicifolius* and *Derris heterophylla*, with the densities consecutively from 46000 to 83583, and 1000 to 23938 individuals per ha. Both of these species had coverage almost 100% of the mangrove vegetation. It means the mangrove forest floor was dominated by *Achantus ilicifolius* and *Derris*

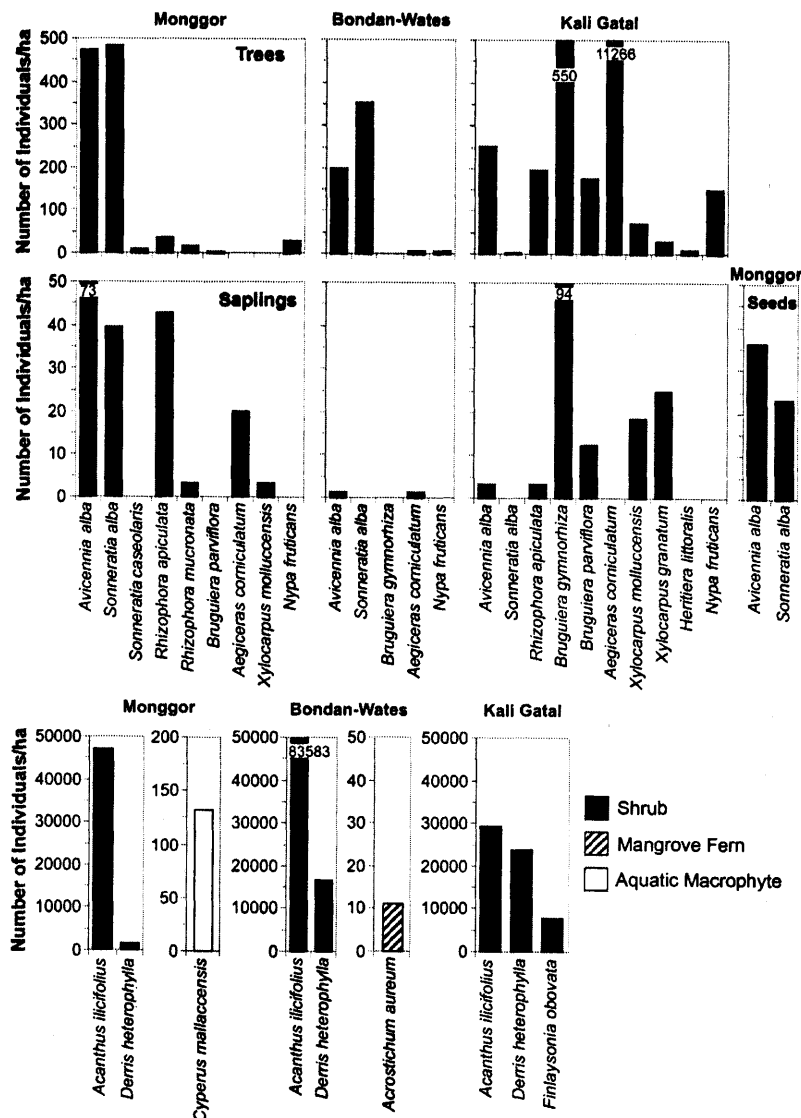


Figure 2. Total densities of mangrove vegetation at three locations of Bondan, Monggor, and Kali Gatal. The locations were dominated by *Acanthus ilicifolius* and *Derris heterophylla*.

heterophylla, mangrove shrub and liana-shrubs.

The co-dominant tree species were *Sonneratia alba* and *Avicennia alba*, and their presence were suppressed by *A. ilicifolius* and *D. heterophylla*.

Both of these species, *Acanthus* and *Derris*, had r and k strategies. It means when they occupied the large gap-canopy areas, they out-competed with the seedlings of mangrove trees (Fig.2; Fig.3). As a result, at Segara Anakan almost all the areas were colonized by mangrove shrub and liana, and the mangrove trees was distributed scarcely.

Thus, the mangrove-tree species were threatened. Therefore, the mangrove of Segara Anakan was as an endangered ecosystem. In addition to the heavy siltations, its ecological services in the seascape is in question. *Bruguiera* spp. and *Rhizophora* spp. were very rare, thus they were locally endangered species. The saplings of tree species were also distributed rarely, because they were suppressed by the colonization of the mangrove shrub and liana, *A. ilicifolius* and *D. heterophylla*. At Bondan, the only saplings found were *Sonneratia alba* and *Avicennia alba*.

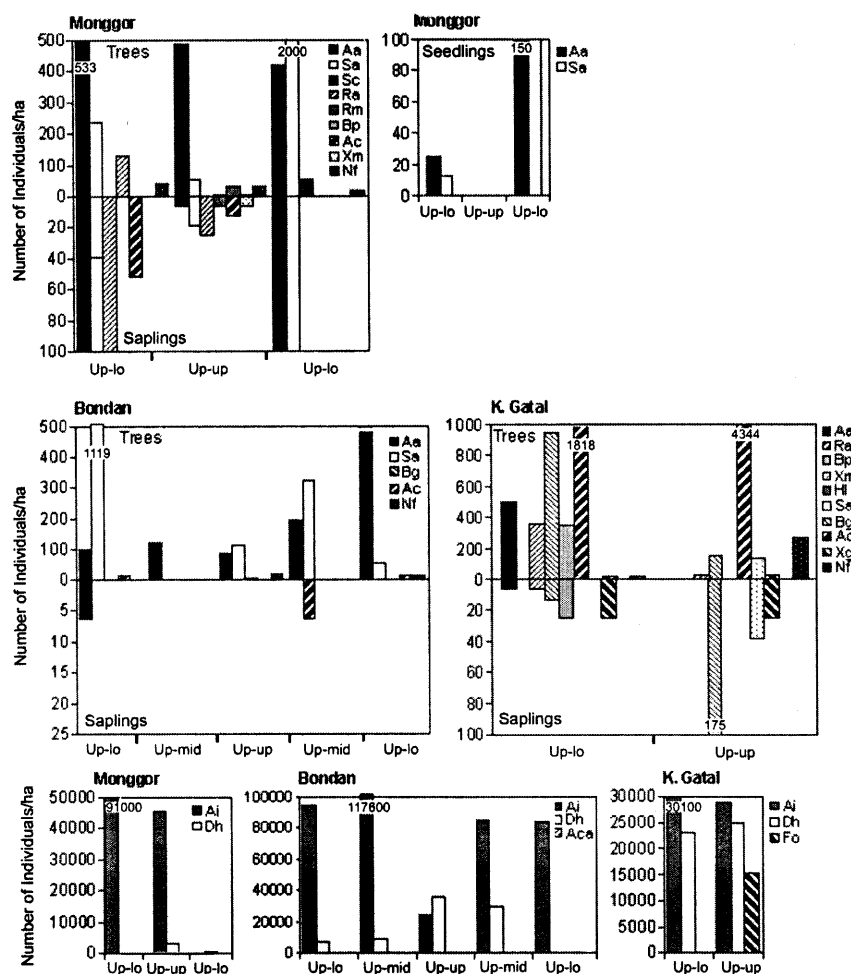


Figure 3. Total densities of mangrove vegetation at the three locations of which were distributed along the transect of Bondan, Monggor, and Kali Gatal. The locations was dominated by *Acanthus ilicifolius* and *Derris heterophylla*. Note: Aa = *Avicennia alba*, Sa = *Sonneratia alba*, Sc = *Sonneratia caseolaris*, Ra = *Rhizophora apiculata*, Rm = *R. mucronata*, Bp = *B. parviflora*, Ac = *Aegiceras corniculatum*, Hl = *Heritiera littoralis*, Bg = *Bruguiera gymnorrhiza*, Xm = *Xylocarpus molluccensis*, Xg = *X. granatum*, Nf = *Nypa fruticans*, Ai = *Acanthus ilicifolius*, Dh = *Derris herterophylla*, Fo = *Finlaysonia obovata*, Aca = *Acrostichum aureum*. Up = upper, lo = lower and mid = middle zones.

In contrast, at Monggor there were no sapling of *Bruguiera gymnorrhiza*. It means the future trees of *B. gymnorrhiza* were also threatened. The dominant tree species at Bondan-Wates and Monggor was *S. alba*, which had density in consecutively around 199 to 353, and 475 to 485 individual per ha. The mangrove of Monggor was at the newly formed land, which was around 10 years old.

The species found at Kali Gatal were *S. alba*, *R. apiculata*, *B. gymnorrhiza*, *B. parviflora*, *A. corniculatum*, *Xylocarpus moluccensis*, *X. granatum*, *Heritiera littoralis*, and *Nypa fruticans*. The *X. molluccensis*, *X. granatum*, and *H. littoralis* were found only at the upper-upper zone. However, at Bondan-Wates and Monggor, the *R. apiculata*, *S. caseolaris*, *R. mucronata*, and *Bruguiera parviflora* were not found,

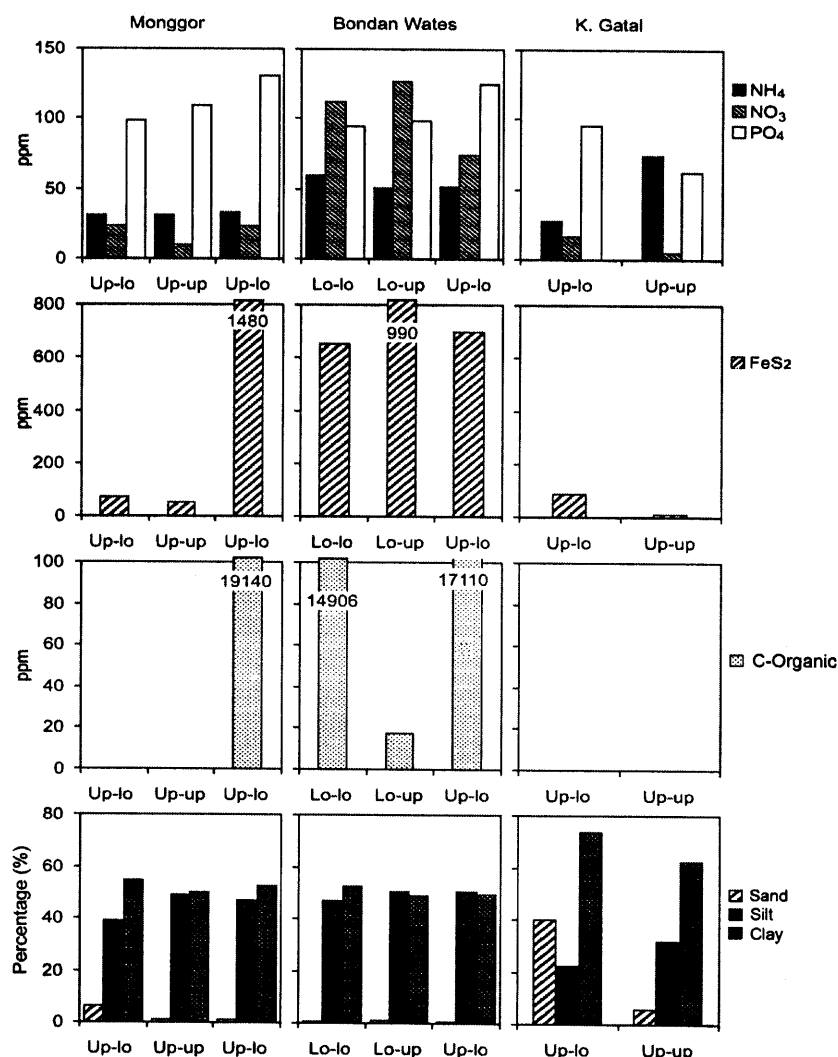


Figure 4. The soil nutrients of NH_4 , NO_3 , FeS_2 , C organic, and soil textures at the study sites of Bondan, Monggor, and Kali Gatal.

and these species were only occurred at Kali Gatal. Why these species did not occur at Bondan-Wates and Monggor, since at these locations, there were not available of the tree propagules. Eventhough the propagule from Kali Gatal areas would possibly dispersed to Bondan-Wates and even Monggor areas during high tide, but they will not survive due to coverage of mangrove shrub and liana, which prevented these tree propagules to grow.

In contrast to the mangrove trees of Bondan-Wates, and Monggor, at Kali Gatal the dominant and co-dominant tree species were *Aegiceras corniculatum*, *B. gymnorhiza*, and *Avecinnia alba*. At the

upper-upper zone, the dominant trees were *A. corniculatum*, *B. gymnorhiza*, and *N. fruticans* (Fig. 3). The *Hiritieria littoralis* were found only at the upper-upper zone. But at Bondan and Monggor, the *R. apiculata*, *S. caseolaris*, *R. mucronata*, and *Brugueira parviflora* were not found. **Soil nutrients** – At Bondan and Monggor, the FeS_2 concentrations were high between 650 to 1485 mg kg^{-1} . In contrast, at Kali Gatal, their concentration were between 10.3 to 86 ppm (Figure 4). The high concentration of FeS_2 increased the soil acidity. It seems that the soils qualities were in the range of mangrove vegetation to grow. However, the mangrove tree species had the K strategy,

which had slow growth. The fast growing shrub and liana had r strategic species.

The mangrove-tree cutting in huge areas created a large gap area. These conditions were responded by the fast growing of mangrove shrub and liana, *A. ilicifolius* and *D. heterophylla*. Both of these species had not only r but also k strategic species, thus both them had spread rapidly and colonized all the mangrove areas. Those *A. ilicifolius* and *D. heterophylla* had prevented the growth of mangrove-tree seedlings. Thus at the Segara Anakan, the distribution and abundant of the mangrove tree species were more dictated by the availability of the propagule-tree species due to the mangrove-tree cutting in comparison to the conditions of the nutrients, soil textures, salinity and siltation. **Water quality** – This study showed that during rainy season, April to May, 2007, the water salinity was 4 ‰ at the all study sites. In contrast during the dry season, September to October, 2007, the salinities were between 39-40 ‰ (Djohan et al. 2009; Djohan 2010). Thus, the water salinity varied highly between wet and dry seasons. During the rainy season, the Segara Anakan mangrove ecosystem was in the process of changing from euryhaline into hypo-haline. But during the dry season they became hyper-haline again. This means that in the Segara Anakan mangrove there were no daily variation of salinities. This condition caused by the combination of heavy sedimentation and climate change. As a result, these conditions were harsh to the mangrove communities.

Overall, in the comparison to the mangrove dynamics between the old-world and new-world tropical mangrove was that in the Segara Anakan mangrove vegetation, their present were due to the anthropogenic activities through the mangrove-tree cutting, and heavy siltation. These activities dictated the mangrove-tree distribution. The large gap of tree-canopy areas were colonized by the mangrove shrubs and liana, *A. ilicifolius* and *D. heterophylla*. As a result, the mangrove tree-species were lost to both of these shrub species. The tree species cutting and the present of *A. ilicifolius* and *D. heterophylla* at large areas changed the

mangrove tree-species composition in the Segara Anakan.

CONCLUSIONS

The Segara Anakan mangrove was in a disturbed condition and critically endangered ecosystem. Almost all the areas were colonized by shrubs of *Acanthus ilicifolius* and liana shrub of *Derris heterophylla*. Both of these species had r – k strategy, which had coverage almost 100%, and had densities in consecutively 83583 and 23938 individual per ha. In contrast, the dominant tree species were *Avicennia alba* and *Sonneratia alba* with densities between 485 to 203 individuals per ha. The salinity varied seasonally, between hypo-haline in the rainy season, and hyper-haline in the dry season. The climate change which combined with the heavy sedimentation, the tree cutting, and land clearing worsen the Segara Anakan mangrove ecosystem.

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